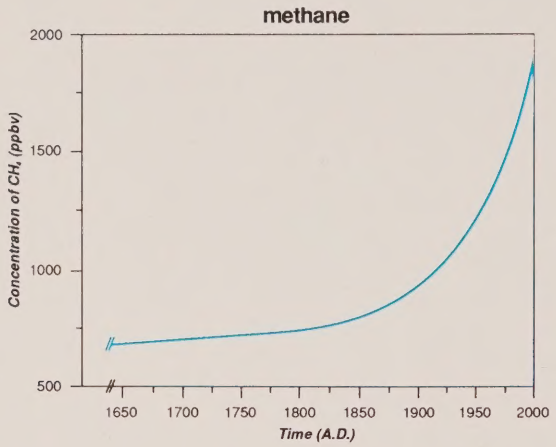
THE CANADIAN NORTHERN WETLANDS STUDY

NOWES

FOREWORD

CHANGES IN ATMOSPHERIC METHANE FOR THE PAST 400 YEARS



After remaining relatively constant for more than 10,000 years, the concentration of methane (CH_4) in the Earth's atmosphere has doubled in the last 100 years.

Next to carbon dioxide, methane is the most important naturally occurring greenhouse gas in the atmosphere and therefore, can contribute significantly to changes in global climate.

It is estimated that wetlands, particularly in the north, account for 15 to 40% of the total amount released to the atmosphere annually from all sources. Improved estimates of CH_4 emissions from wetlands are required if the relative impact on climate of current and future anthropogenic emissions is to be determined.

The reason for the increased atmospheric burden of CH_4 is not well understood. Wetland methane is formed mainly by anaerobic biological processes. The dependence of methane production on such factors as nutrient content of the water, the quantity and composition of the organic matter, soil moisture and temperature, vegetation type and water table is not well known.

The vast wetland, peat and tundra areas of Northern Canada can also influence other important gases in the global atmosphere (e.g. CO_2, N_2O).

The Canadian Northern Wetlands Study (1989 to 1991) focusing on a summer intensive in 1990 is recognized internationally as a major project (NOWES) in the International Global Atmospheric Chemistry Program (IGAC). IGAC in turn is part of the International Geosphere Biosphere Program on Global Change (IGBP) of the International Council of Scientific Unions (ICSU). IGBP aims at understanding the entire Earth system, including the ability to predict changes due to natural variability, and those associated with human activities on a global scale over decades and centuries.

Further copies of this brochure can be obtained from the Air Quality and Inter-environmental Research Branch, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario, Canada, M3H 5T4

PROJECT MANAGEMENT

OBJECTIVES

To assess the importance of Northern Wetlands as sources of biogenic gases to the atmosphere under current and future climate scenarios by:

1. Investigating the atmospheric chemistry of biogenic gases and related compounds in the Hudson Bay Lowlands with emphasis upon carbon gases.
2. Understanding the physical, chemical, and biological processes influencing biogenic gas production and exchange and the sensitivity of the source/sink to global climate change.
3. Determining the significance of the Northern Wetlands as a source of biogenic gases to the atmosphere globally.
4. Characterizing the past and present ecology of wetlands.

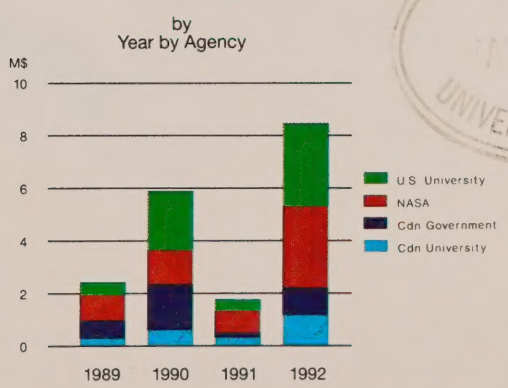
ORGANIZATION

This study is coordinated by the Canadian Institute for Research for Atmospheric Chemistry (CIRAC).

STEERING COMMITTEE

- WETLANDS SECRETARIAT – CIRAC
- GROUND BASED STUDIES
- AIRCRAFT FLUX OBSERVATIONS
- AIR CHEMISTRY OBSERVATIONS
- MODELLING/REMOTE SENSING
- ECOSYSTEM CHARACTERIZATION

BUDGET



BACKGROUND AND PARTNERS

HISTORY/MILESTONES

Oct. 1987	Scientists of Atmospheric Environment Service (AES) and of the NASA Global Tropospheric Experiment meet.
Jan. 1988	AES, Toronto. First Canadian workshop on northern wetlands. Sponsored by CIRAC, AES and the Royal Society of Canada.
July 1988	Submission of a collaborative research grant proposal by CIRAC to the National Science and Engineering Research Council (NSERC) of Canada on behalf of a consortium of Canadian university, government and private industry.
Feb. 1989	Approval of collaborative grant by NSERC.
Mar. 1989	AES, Toronto. Second Canadian wetlands workshop.
Oct. 1989	AES, Toronto. Third Canadian wetlands workshop.
Nov. 1989	Washington, NASA/ABLE 3B planning workshop.
Summer 1990	Execution of intensive field program centred on the Hudson Bay Lowlands and Northern Quebec/Labrador.
Feb. 1991	AES, Toronto. International data analysis workshop. Sponsored by CIRAC/NASA.
May 1991	Baltimore. Special session on Canadian Wetlands Study at spring meeting of American Geophysical Union.
July 1991	Deadline submission of short papers to a dedicated issue of Geophysical Research Letters.
Jan. 1992	Deadline submission of articles to dedicated issue of Journal of Geophysical Research.

PARTNERS

UNIVERSITIES

Canadian

McGill
McMaster
York
Waterloo
Manitoba
Alberta
Trent
Guelph
Windsor

Non-Canadian

Colorado State (FC)
California (Irvine)
Georgia Tech
SUNY (Albany)
New Hampshire
Harvard
Maine
Delaware
North Carolina

GOVERNMENT AGENCIES

Canadian - Federal

Environment Canada
- Atmospheric Environment Service
- National Water Resources Institute
- Inland Waters Directorate - Ont. Region

Fisheries and Oceans
- Freshwater Institute

Energy, Mines and Resources
- Canada Centre for Remote Sensing

National Defence
Agriculture Canada

Canadian - Provincial

Ontario Ministry of Natural Resources
- Ontario Centre for Remote Sensing

Ontario Hydro

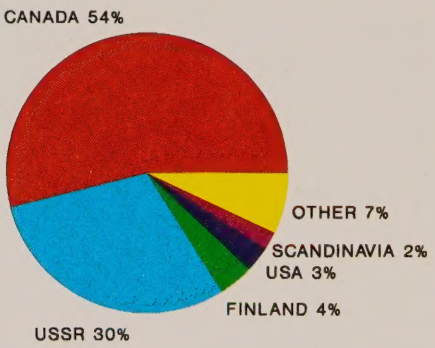
Non-Canadian

NASA, Global Tropospheric Experiment
National Centre for Atmospheric Research
New York State Department of Health
CSIRO Aspendale Australia
Soviet Union Observers
Woods Hole

WHAT ARE WETLANDS?

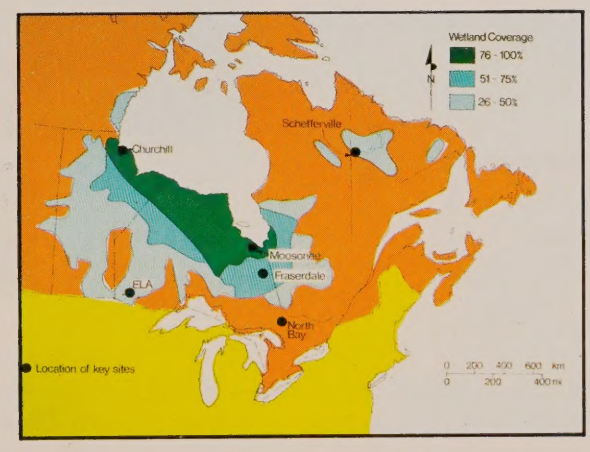
Wetlands are defined as "land that has the water table at, near, or above the land surface, or which is saturated for a long enough period to promote wetland or aquatic processes" (C. Tarnocai, *Canadian Wetland Registry,* 1980). As a result of saturated conditions which usually lead to chemical reduced conditions and a large supply of organic material in the form of peat, wetlands are an ideal environment for the biogenic production of carbon, nitrogen, and sulphur gases. A majority of Northern Wetlands underlain by peat are called peatlands.

DISTRIBUTION OF WORLD PEATLANDS



Relative distribution of peatlands by country (adapted from J. Taylor, *Peatlands of Great Britain and Ireland,* 1983). Total cover of wetlands in the Polar and Boreal zones is approximately 2,758,000 km², of which 88% are peatlands.

THE NOWES REGION



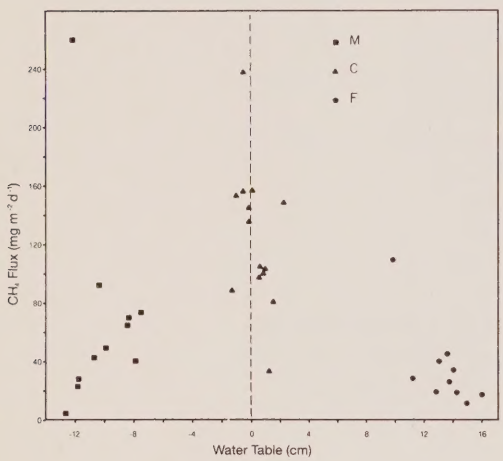
The percentage land covered by wetlands in the NOWES region. Areal location of the principal field sites (from National Wetlands Working Group, *Wetlands of Canada,* 1988).

GROUND BASED

CHAMBER MEASUREMENTS

Box-like covers called flux chambers placed on the surfaces of the peatland are used to collect biogenic gases emitted from a small area (< $1m^2$) of the ecosystem. In this study, fluxes of CH_4, N_2O, NO_x, and non-methane hydrocarbons are measured using chambers. Areally weighted gas flux can be derived using the percentage coverage of ecosystem types. Measured environmental variables that correlate with gas fluxes, include ecosystem productivity, peat temperature, moisture and chemistry as well as water chemistry.

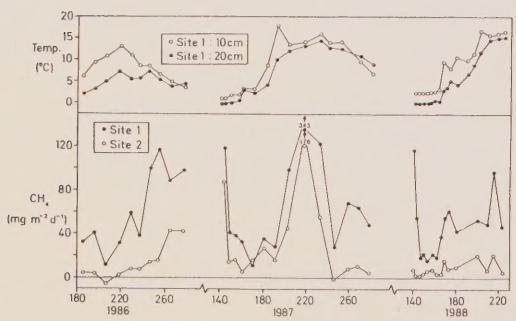
CH_4 Emissions Dependence on the Water Table



(Left) Relationship between the location of the water table and CH_4 emissions from a sub-arctic mineral-poor fen. When the water table is at the surface, the gas flux is the greatest. Emissions are reduced when the water table is below the surface because of oxidizing conditions, and when the water table is above the surface because the peat is cooler (T. Moore et al., unpublished manuscript).

(Right) Flux chambers used to measure CH_4 emitted from a sub-arctic wetland near Schefferville, Quebec.

CH_4 Emissions Dependence on Temperature



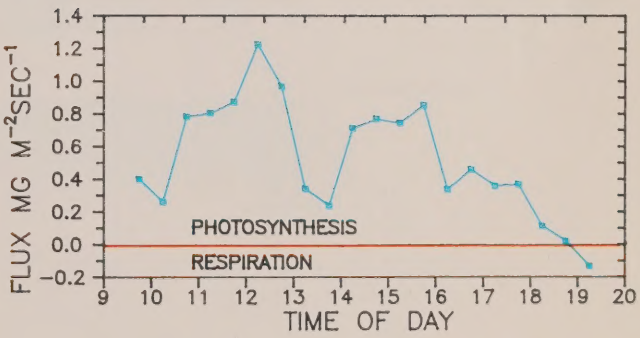
Methane emissions from a sub-arctic mineral-poor fen (Site 1) and a mineral-rich fen (Site 2), with temperature at 10 and 20 cm depths in the mineral-poor fen. Methane emissions increase as the peat soil warms (T. Moore and R. Knowles, *Biogeochemistry,* 1990).

STUDIES

TOWER FLUX MEASUREMENTS

An alternative approach to chambers in determining gas exchange between atmosphere and wetlands is offered by micrometeorological eddy correlation techniques utilizing a tall tower. This provides emissions over a larger scale (100 to 1000m) than chambers (1m) and with a time resolution of half an hour.

The 20 metre tower (left) will be placed in a Hudson Bay Lowland wetland 100 km west of Moosonee, Ontario. Instrumented with fast response CH_4, CO_2, O_3, temperature, and vertical wind sensors the correlation between vertical wind and the other measured variables will yield vertical fluxes. The tower is jointly operated by researchers from the Atmospheric Environment Service and the University of Guelph.



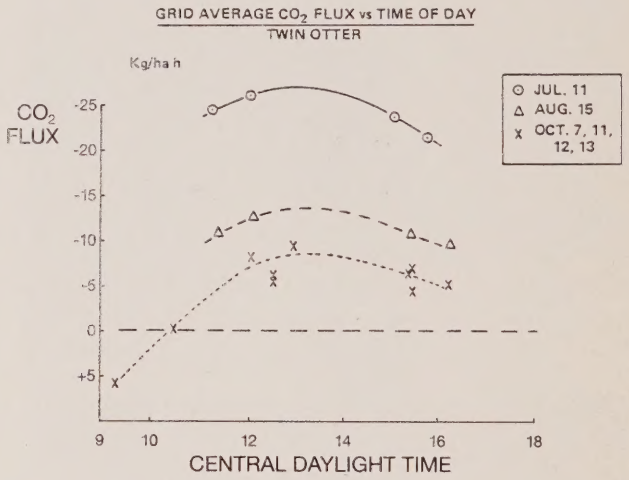
A time series of CO_2 flux between atmosphere and a forest canopy measured using micrometeorological techniques like those used on the wetlands tower above. Positive values of flux indicate that CO_2 is being taken up by the forest as a result of photosynthesis. Negative values indicate a net CO_2 release as a result of respiration dominating the air-surface exchange.

AIRCRAFT FLUX

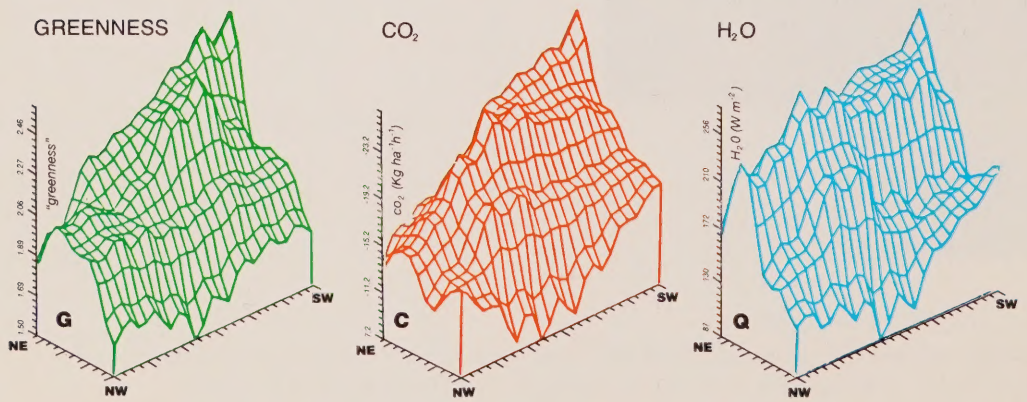
CANADIAN NATIONAL RESEARCH COUNCIL (NRC)

The Twin Otter atmospheric research aircraft operated by the National Aeronautical Establishment of NRC has been used for 15 years in weather modification, air pollution, and trace gas flux studies. Its low speed and manoeuvrability make it an ideal platform for boundary layer studies at altitudes down to 15 metres. For NOWES it will carry wind-measuring instrumentation and fast-response gas analyzers for computing fluxes of sensible and latent heat, momentum, CO_2, and CH_4.

NAE Twin Otter



(above right) Carbon Dioxide Fluxes (in Kg per hectare per hour) measured by the NAE Twin Otter over Kansas grassland during participation in the NASA FIFE-87 project. Each point represents the average of eight 15-km runs flown in a grid pattern at an average altitude of 100 m.



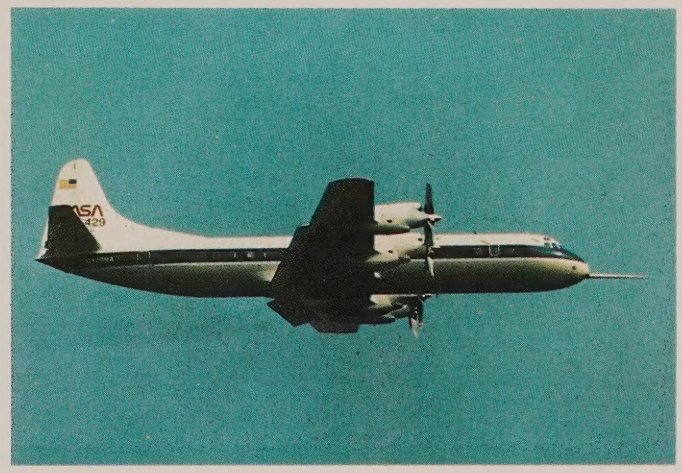
Observations of the greenness index (G) a measurement of photosynthesis and the flux of carbon dioxide (C) and water vapour (Q) measured by the NAE Twin Otter over the NASA FIFE site in central U.S.A. on August 12, 1989.

OBSERVATIONS

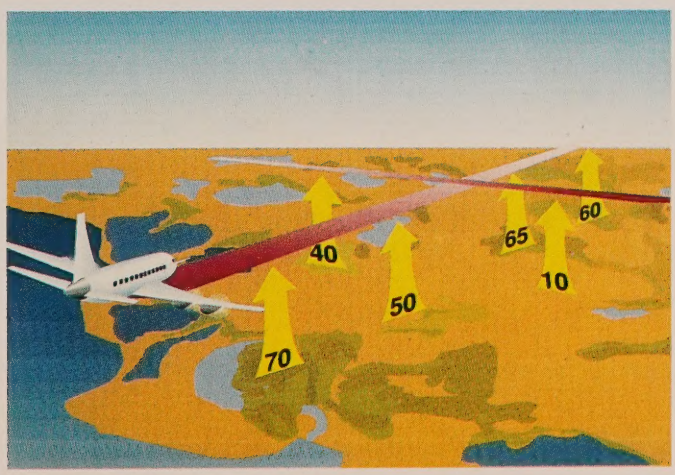
NASA ABLE 3B TRACE GAS FLUX MEASUREMENTS

The NASA Atmospheric Boundary Layer Electra aircraft can measure the flux of CO_2, CH_4, and O_3 in addition to the concentration of many tropospheric gases. The Electra and the Canadian Twin Otter will fly several coordinated experiments in the Hudson Bay Lowlands. In addition, the Electra will measure trace gas fluxes and atmospheric chemistry over northern Labrador and Quebec in support of the NASA tower program based in Schefferville, Quebec.

NASA Electra



Airborne measurements of the methane source strengths (shown in the figure as milligrams of methane per meter squared per day), were measured during flights over the Yukon - Kuskokwin delta in southwestern Alaska. There is a high correlation between the release of the methane to the atmosphere and the type of underlying terrain. Highest releases are from the wet lowland regions (green) and lowest from the dry upland regions (brown).



AIR CHEMISTRY

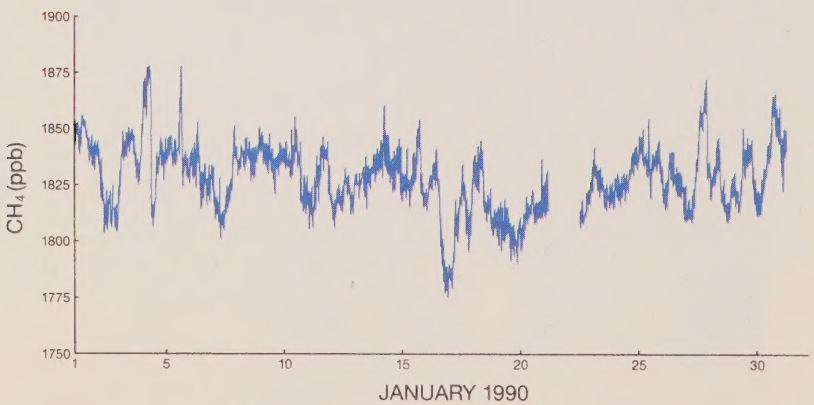
LONG TERM BASELINE OBSERVATIONS

In December 1989, a baseline air chemistry observatory was established by the Federal Atmospheric Environment Service and Ontario Hydro at Fraserdale. It is located 150 km north of Timmins, Ontario in the boreal forest just south of the Hudson Bay wetlands. The purpose of the lab is to obtain a 5 to 10 year record of the abundance of greenhouse gases such as methane and carbon dioxide in the atmosphere over northern wetlands and boreal forest. In addition, temperature, humidity, and wind speed as well as indicators of pollution such as black carbon are being measured. The seasonal variations and dependence of greenhouse gas concentrations on wind direction will yield insight into wetland-atmosphere exchange processes. The laboratory will serve the needs of not only NOWES but also those of the Boreal Forest Experiment, another major collaborative effort between Canadian scientists and NASA planned for 1993 and 1994.

FRASERDALE OBSERVATORY

GAS CHROMATOGRAPH CONTINUOUSLY MEASURING CARBON DIOXIDE/METHANE

Data are transmitted to the Atmospheric Environment Service in Toronto by telephone on a daily basis.



Methane gas concentrations observed in January 1990 at Fraserdale.

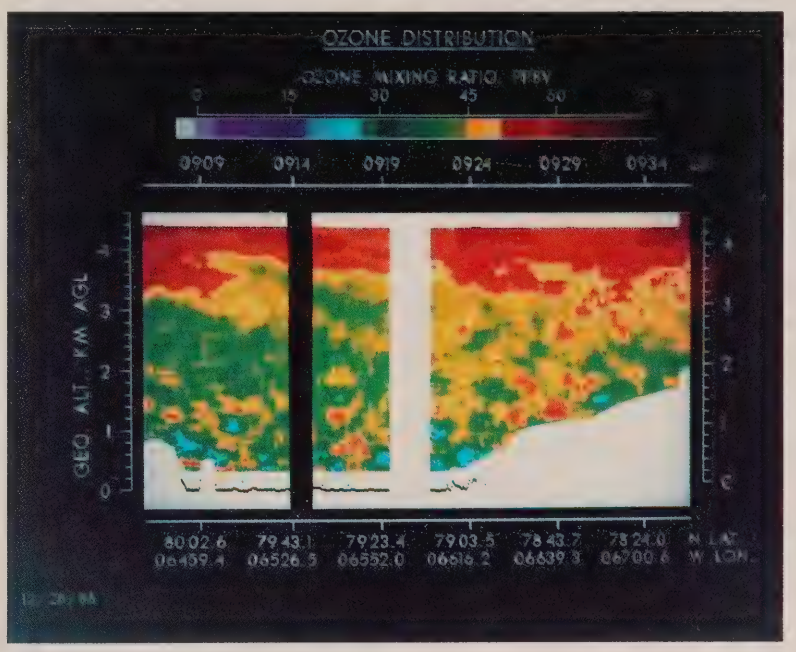
OBSERVATIONS

SHORT TERM STUDIES

An intensive short term air chemistry study will be mounted at the McGill University sub-arctic research station near Schefferville, Quebec by Harvard University during summer 1990. Chemical reactions involving wetlands and boreal forests under relatively clean atmospheric conditions will be investigated.

The ABLE 3B studies in the Schefferville area will follow the same type of experimental design as discussed above for the Hudson Bay Lowland studies. Two micro meteorological towers will continuously characterize fluxes of CH_4, CO_2, O_3, selected nitrogen gases, and meteorological parameters. One tower will be located in a woodland environment and the other in a wetland.

The NASA Electra aircraft will conduct regional air chemistry observation which when combined with previous Canadian studies of wetland hydrology and CH_4 emissions in the Schefferville area will provide the basis for comparison of continental interior ecosystems to the Hudson Bay Lowlands which have a significant maritime influence.

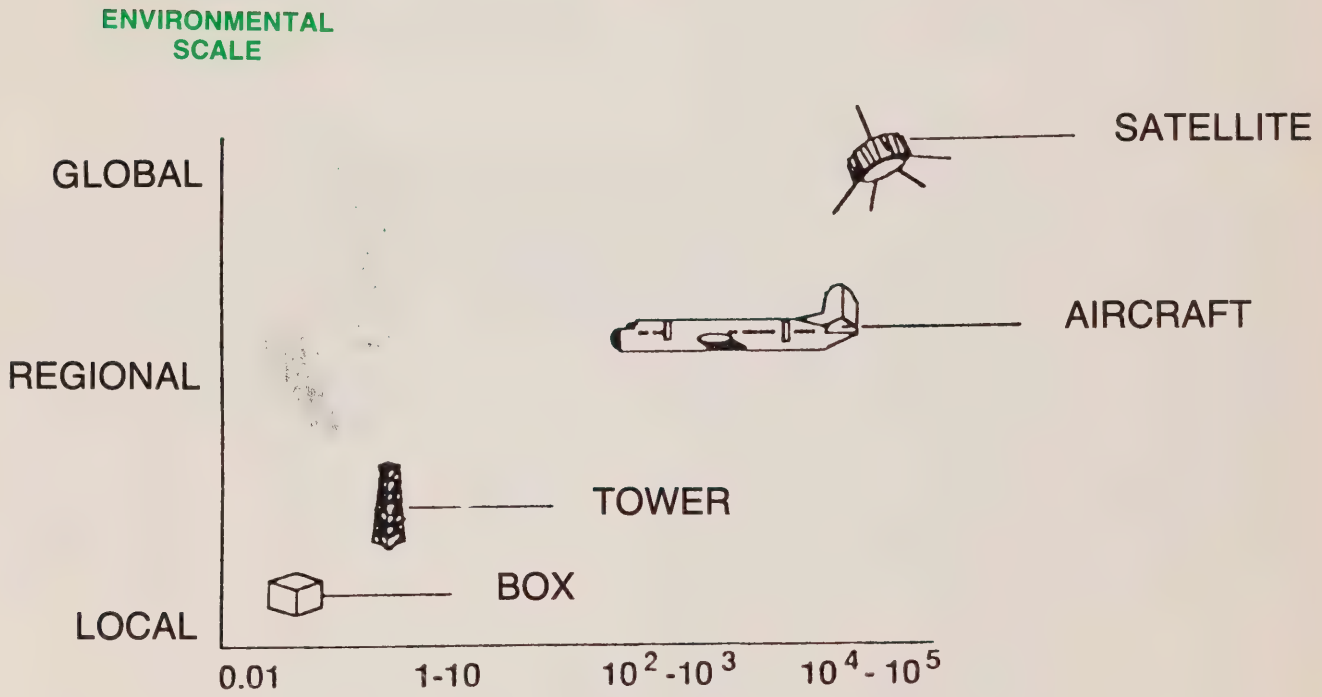


Atmospheric ozone concentration cross sectional vertical profile measured off the coast of Greenland in summer 1985. Measurements were obtained using laser LIDAR (LIght Detection And Ranging) remote sensor on board the NASA Electra aircraft. Concentrations increase with altitude. Pockets of ozone rich air are seen penetrating from above into the lower atmosphere.

LARGE SCALE METHANE

The problem: How to scale-up local observations to a regional scale CH_4 flux estimate.

The large spatial variation of CH_4 gas emission poses a problem in assessing the contribution of Northern Wetlands to total global CH_4 emissions. This necessitates a multidisciplinary approach to measurement ranging from small scale chambers at the 1 m scale to micrometeorological towers at 100 m scale to aircraft at scales of 5 - 50 km to satellite remote sensing on scales of 100s' of km.



A schematic illustration of the relationship between measurement techniques and platforms and the typical coverage provided by their observations. (adapted from Harriss, R.C. 1989 in *Exchange of Trace Gases between Terrestrial Ecosystems and the Atmosphere,* M.O. Andreae and D.S. Shimel, ed.).

***1 HECTARE = 100m x 100m area**

EMISSIONS: A SCALE-UP PROBLEM

Images of the Kinoshe Lake intensive study area west of Moosonee in the Hudson Bay Wetlands at different scales.

SCALE

100s of kms

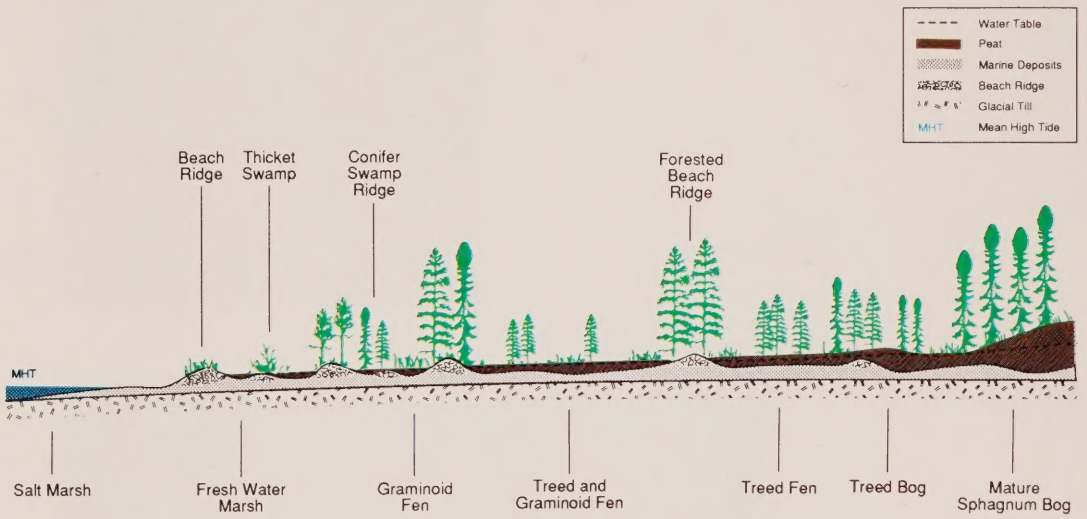
1-10 of kms

10s of metres

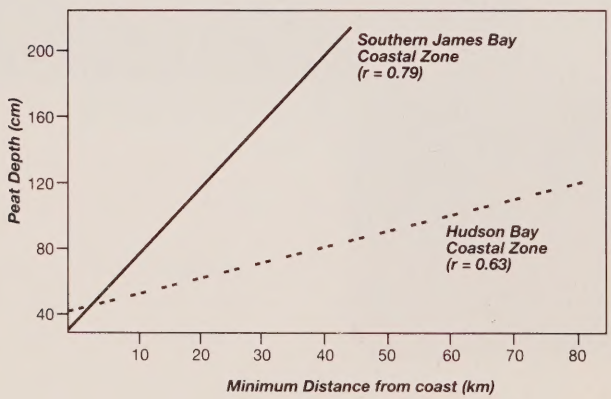
A wetlands land-use classification being developed in the study will be used with scale-up techniques developed in the study to estimate the total emissions of CH_4 from Canadian northern wetlands.

ECOLOGY OF THE HUDSON BAY WETLANDS

This project will build on existing research in Canada of the ecology of the Hudson Bay Wetlands. At sites along a transect from the coast into the interior at Kinoshe Lake where gas fluxes are measured, intensive ecological characterization will be done. This includes the examination of past-environments using peat cores. The evaluation of historical conditions in association with studies of the current behaviour of the ecosystem will assist in determining the changing nature of atmospheric greenhouse gas exchange.



Schematic cross-section representing the Hudson Bay Wetlands' portion near Moosonee, Ontario (modified from Wickware et al., 1980).



Relationship between the age of the peatlands and distance from the Wetlands coast based on several transects in the James Bay area (taken from R. Protz et al., *Canadian Journal of Soil Science,* 1988).

CONTACTS

For further information contact the following scientists:

Walter Glooschenko (Program Coordinator)
Canadian Institute for Research in Atmospheric Chemistry
006 Steacie
York University
4700 Keele Street
North York, Ontario M3J 1P3
Phone: (416) 736-5586
Fax: (416) 736-5690

Ian J. MacPherson (Canadian Aircraft)
National Research Council
Flight Research Lab
Bldg. U-61 Montreal Road
Ottawa, Ontario K1A 0R6
Phone: (613) 998-3014
Fax: (613) 952-1704

Nigel Roulet (Hudson Bay Lowland Ground-Based Program)
Geography Department
N430 Ross Bldg.
York University
4700 Keele Street
North York, Ontario M3J 1P3
E-mail ROULET@YORKUMI
Phone: (416) 736-5107
Fax: (416) 736-5735

Leonard Barrie (Canadian Atmospheric Chemistry)
Atmospheric Environment Service
4905 Dufferin Street
Downsview, Ontario M3H 5T4
Phone: (416) 739-4868
Fax: (416) 739-4521

Tim Moore (Schefferville Study)
McGill University
Department of Geography
Burnside Hall
805 Sherbrooke Street West
Montreal, Quebec H3A 2K6
Phone: (514) 398-4961
Fax: (514) 398-3594

Robert C. Harris (NASA/ABLE 3B)
Institute for the Study of Earth, Oceans, and Space
University of New Hampshire
Science and Engineering Research Centre
929 College Road
Durham, New Hampshire 03824, USA
Phone: (603) 862-3875
Fax: (603) 862-1915

Gary Whiting (BREW)
NASA/Langley Research Centre
Mail Stop 483
Hampton, Virginia 23665-52, USA
Phone: (804) 864-5845
Fax: (804) 864-3800

Steve Wofsey (Schefferville ground-based program ABLE 3B)
Center for Earth and Planetary Physics
Pierce Hall, 29 Oxford St.
Harvard University
Cambridge, Mass. 02138, USA
Phone: (617) 495-4566
Fax: (617) 495-9837

Patrick Zimmerman (NCAR)
National Centre for Atmospheric Research
P.O. Box 3000
Boulder, Co. 80307, USA
Phone: (303) 497-1406
Fax: (303) 497-1400

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